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Possible adverse effects of sea-level rise on islands and coastal areas, particularly low-lying coastal areas

Report of the Secretary-General

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I. INTRODUCTION

1. On 22 December 1989, the General Assembly adopted resolution 44/206, entitled "Possible adverse effects of sea-level rise on islands and coastal areas, particularly low-lying coastal areas". In the resolution the Assembly, expressing concern that sea-level rise resulting from global climate change could lead, inter alia, to abnormally high tides, which could intensify flooding and the erosion of coastal areas and damage infrastructure on islands and in low-lying coastal areas, welcomed the attention being given to the potentially serious effects on islands and coastal areas of sea-level rise resulting from climate change; urged support to countries so affected, particularly developing countries, in their efforts to develop and implement strategies to protect themselves and their vulnerable natural marine ecosystems from the particular threats of sea-level rise; requested the Secretary-General to invite the United Nations Environment Programme (UNEP), the World Meteorological Organization (WMO) and, through them, the Intergovernmental Panel on Climate Change (IPCC) to take account in their work of the particular situation of islands and coastal areas; recommended that the issue be considered during discussions of a draft framework convention on climate, and at the United Nations conference on environment and development in 1992; and requested the Secretary-General to report on the implementation of the resolution to the General Assembly at its forty-sixth session, through the Economic and Social Council and the Governing Council of UNEP. The present report was prepared in response to that request.

II. GLOBAL CONCERNS

2. The problems caused by or associated with the potential impact of expected climate changes, such as the predicted rise in sea level, may prove to be among the major environmental problems facing marine and adjacent coastal areas over the next century. The areas which are likely to be most profoundly affected are the low-lying islands and coastal zones of the world where more than 70 per cent of the world's population currently lives. A rising sea level will add to the problems already faced by increasingly crowded and overstressed coastal areas.

3. In spite of uncertainties surrounding the predicted climatic changes, greenhouse gases have accumulated in the atmosphere to such a level that changes may have started already and their continuation may now be inevitable. Global warming, on a scale not experienced in the last 100,000 years, is expected to occur before the end of the next century. Predicted changes in temperature, precipitation and radiation budgets, as well as in patterns of atmospheric and oceanic circulation, are expected to produce a gradual rise in sea level as a result of thermal expansion of water in the oceans and a reduction in the water stored in ice and snow on land. The consensus view now suggests that the mean sea level may rise between 8 and 30 centimetres by the year 2030, with a best estimate of 18 cm. By 2070 the projected range is 21 to 71 cm, with a best estimate of 44 cm. Globally this

would not, in itself, have a significant impact. However, locally, relative changes could be as much as five times this value owing to factors such as subsidence, sediment compaction and oil, gas or groundwater extraction. While the prospect of immediate inundation of large areas of the world's coastline has receded, time lags in the response of the oceans and other global systems to a rising global temperature could mean a continuing and possibly accelerating rise in sea level later. More severe impacts can also be expected if sea level rise exceeds the anticipated increase, or if the rate of the increase exceeds the capability of sensitive coastal ecosystems to respond.

4. In the longer term, the rise in sea level will dramatically affect coastal areas, inundating lowland areas, eroding beaches, exacerbating flooding and increasing the salinity of soils, groundwater, rivers, estuaries, lagoons and aquifers. Such physical changes will affect the suitability of the coastal zone and its resources for use by human populations, for example by damaging coastal agriculture and contaminating drinking-water supplies. They will also lead to a wide variety of biological changes at the population, community and ecosystem level. For instance, an increase in tropical ocean water temperatures of only 1 to 2°C may cause coral bleaching and die-back, which combined with other stresses on coral reefs may reduce their ability to grow and keep up with rising sea levels, making them less effective as breakwaters and reducing their value as tourism resources. The frequency, intensity and duration of extreme meteorological events, including tropical storms, storm surges and associated torrential rainfalls, if increased as predicted by some experts, will cause greater destruction to coastal areas and islands through excessively high water, flooding and wave damage added to higher sea levels.

5. Other future impacts on society and the coastal environment from pressures such as population growth, migration to coastal areas, excessive or unwise development and overexploitation of resources may far exceed the direct impacts of sea-level rise. However, such factors will increase the vulnerability of societies to damage from sea-level rise and other climate-related changes, and may trigger impacts of unmanageable proportions. Some of the most adverse consequences can be diminished or mitigated if society takes timely anticipatory action.

6. Owing to their obvious susceptibility to sea-level rise and climatic changes, combined with the high profile adopted by their political leaders in various international forums, small island States have received particular attention in impact assessments of global change. In addition, countries such as Bangladesh, which has been subject to devastating episodic flooding, are also considered de facto to be at high risk.

III. UNITED NATIONS EFFORTS AT THE REGIONAL LEVEL

7. The impacts associated with expected sea-level rise and related climatic changes on islands and low-lying coastal areas will vary from region to region, depending on regional characteristics and responses to climate

change. To review these differences, regional task teams on the implications of climatic changes were established by UNEP, in cooperation with the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and other United Nations agencies and regional organizations, for nine of the regions covered by the UNEP Regional Seas Programme. All task teams have worked according to the same terms of reference and are centrally coordinated by UNEP to ensure comparability of their analyses. Several other assessments in different regions have also been organized. Their conclusions for some of the regions are summarized here.

A. The Mediterranean

8. For the 18 countries of the Mediterranean, surrounding a semi-enclosed sea, climate changes are likely to lead to an increase in land degradation, deterioration of water resources, decline in agricultural production and damage to natural terrestrial and aquatic ecosystems. Future impacts on Mediterranean society resulting from non-climatic factors (e.g. population increase, mismanagement of coastal zones) may far exceed the direct impacts of climatic change and will cause a continuous increase in society's vulnerability to climatic stress, particularly in the south. Low-lying cities such as Venice and important agricultural areas such as the Nile Delta are particularly susceptible to damage from a rising sea level.

B. The South Pacific region

9. The South Pacific region comprises more than 3,000 small isolated islands, grouped into 24 political entities, including 14 Pacific island States that would be severely or profoundly impacted by even low to medium projected levels of global change. Many of these islands are atolls or low coral islands consisting of sand and rubble piled on coral reefs, which are highly susceptible to the impacts of sea-level rise and for which engineering responses are not feasible. Such islands and island nations are threatened with damage to coastlines and groundwater sources by rising sea levels, or even with total destruction should sea levels rise by more than 1 metre, or should waves and storm surges increase as expected from intensified cyclonic activity in latitudes north and south of about 10°. Sea-level rise will also reduce the land area of small high islands and raised coral islands; flood river deltas, mangrove flats, sandspits and lagoons; damage coastal infrastructure (roads, sewerage, water supply, tourist developments, etc.); increase coastal erosion rates; contaminate groundwater resources; submerge coral reefs; affect coastal agriculture and forestry; and increase the risks to human life and health. Isolated small island States are already economically vulnerable and environmental changes that place increased stress on their subsistence or commercial economic bases are commonly extremely damaging.

10. Human populations from impacted zones and islands may be forced to migrate as environmental refugees. Although the population of the region is relatively small in absolute terms, numbering approximately 5 million people, the cultural diversity is enormous (one third of the world's languages are spoken in Melanesia). The social, political and economic integrity and physical and biological environments of more than 800 separate human cultures will be threatened. Cultural identity, an extremely important concern in the Pacific Islands, is difficult to maintain in migrant communities.

C. South Asian seas

11. The South Asian seas region includes five countries, of which Sri Lanka and Maldives are island nations, and India has significant island territories in the Andaman, Nicobar and Laccadive Islands. Two States (the Maldives and Bangladesh) are considered to be amongst the countries most vulnerable to climate change and sea-level rise. The countries are all densely populated and the coastal areas are heavily utilized for fish and agricultural production and as centres of industry. Changes in oceanic and atmospheric circulation will have adverse impacts on marine food resources, change the frequency, intensity and paths of tropical storms and storm surges, alter precipitation patterns and increase coastal flooding. A rising sea level will only compound the problem. Over one third of Bangladesh could be destroyed by intensive flooding, severe erosion, devastating cyclones and storm surges. These impacts are severe indeed, affecting the lives of many millions of people living in the deltas and low-lying areas. They can threaten unique ecosystems and have enormous negative economic impacts.

12. The Maldives is a State of many atolls, with a total land area of 260 km^2, a maximum height above sea level of around 3 metres, and a population of about 200,000 living on approximately 200 of the 1,200 islands. A number of organizations have prepared reports on its vulnerability to global change. The capital, Male, is an island approximately 1,700 m by 700 m, with a population of 56,000 inhabitants. Population growth has led to land shortage and new land has been created by pumping sand from the lagoon. Most of the island is about one metre above sea level. Although the island is protected by sea walls, flooding is sometimes a problem, particularly on reclaimed land. Given the high porosity of coral and coral sand, the construction of dikes may not be sufficient to solve the problem of a rise in sea level since the underground continuous flow of water would require an immense amount of energy for drainage.

13. A study prepared by UNEP in 1989 at the request of the Government of the Maldives highlighted the dependence of the islands' economy on tourism and fishing, and identified the major environmental problems as coral mining for construction, which destroys the reef surface; land reclamation on the seaward edge, which increases vulnerability to wave surges; modifications to the edges of islands (e.g. jetties and sea walls), which change currents and influence sand movements causing local deposition and erosion problems; and aquifer

drawdown. All these problems increase the vulnerability of the country to the effects of sea-level rise.

D. East Asian seas

14. The East Asian seas region consists of 5 participating countries belonging to the Association of South-East Asian Nations (ASEAN), which includes both coastal and archipelagic States. The region is characterized by numerous islands and extensive coastline lengths. It is also recognized as an area that supports high species and habitat diversity. The rapid population growth, concentrated along the coast, has caused degradation of living resources and their over-exploitation. The region is heavily dependent on the seas and fish forms the major dietary protein source. Sea-level rise is anticipated to have major impacts within the region, particularly on low-lying coastal centres of population.

E. The wider Caribbean region

15. The wider Caribbean region includes low-lying coral islands, volcanic uplands, coastal plains, deltas, coral reefs and wetlands. These characteristics, combined with the region's racial and cultural diversity, make tourism the single most important industry in the region. In islands like the Bahamas, Barbados and Antigua, this is the major foreign exchange earner and employs large numbers of people. The most significant impact of sea-level rise on tourism would be beach erosion. While shoreline migration may lead to the creation of new beaches, the protection and stabilization of existing ones could be burdensome on national economies. When the effects of climate change are coupled with other stress factors (e.g. sand mining, mortality of reefs, etc.), the region's beaches would be highly vulnerable, causing significant dislocation of the economic structures of many of these countries.

16. Coastal vulnerability must be assessed on a case-by-case basis because of the variation in tectonic movements across the region. Minimal impact would be expected in areas where there is crustal emergence (e.g. the north coast of Jamaica, the south-east coast of Cuba, Barbados and the south-west of the Gulf of Mexico). Areas experiencing downwarping and/or subsidence would be among the worst impacted (e.g. the Maracaibo region of Venezuela, the northern part of the Gulf of Mexico from Texas to Florida and the western area of the Gulf of Honduras). The major deltas of the wider Caribbean, especially the Mississippi (United States of America), Magdalena (Colombia) and Rio Grande (Mexico/United States of America) would be likely to experience shoreline retreat, involving thousands of hectares of land, with significant impacts on benthic systems. Coastal lagoons, estuaries and salinas would experience saline intrusion.

F. The African coasts

17. The coasts of both eastern and west and central Africa are characterized by vulnerable economies, large and growing populations, and areas already subject to environmental stress. The coastal countries are dependent to a significant extent on coastal resources. While only a small proportion of the mainland population resides on the coast, on the islands coastal settlement is much more common. A critical factor on the continent is the rapid rate of population growth, resulting in high pressure on resources. Rapid urbanization has led to inadequate water supply, overcrowding and unsatisfactory waste disposal, waste being discharged directly into rivers and the sea. These factors increase the vulnerability of coastal communities, many of which are already subject to rapid coastal erosion, which will accelerate with rising sea levels.

18. There will be impacts from sea-level rise on natural coastal habitats such as coral reefs, lagoons and mangroves. The spatial and temporal distribution of rainfall and cyclones will change and cyclone intensity may be increased, damaging coastal forests and mangroves as well as endangering human communities. The coral reefs will be vulnerable to wave action and sea-level rise, and to sedimentation from increased runoff. As reefs form part of the natural defence systems, this may encourage further coastal erosion. Islands will face problems of water limitation and biodiversity will be reduced. Socio-economic activities and infrastructure such as port facilities, waste disposal and roads are already under stress. Sea-level rise would create additional stress, thus reducing economic performance and growth.

IV. UNITED NATIONS EFFORTS AT THE GLOBAL LEVEL

19. All the pertinent parts of the United Nations system have responded rapidly to the growing problem of expected climatic changes and these efforts are too numerous to list in detail here although many are related to sea-level rise. Some initiatives have focused more specifically on sea-level rise itself.

20. The Intergovernmental Panel on Climate Change (IPCC), jointly established by WMO and UNEP, and the recent Second World Climate Conference refined the international scientific consensus on the probable rate of sea-level rise and the elements of uncertainty in present predictions. Two IPCC workshops were organized on adaptive options and policy implications of sea-level rise and other coastal impacts of global climate change, and UNEP sponsored 19 participants from developing countries, particularly small island States, in these workshops.

21. The specialized agencies have been re-evaluating their existing data to determine the coastal areas most at risk and the implications for human activities.

22. New and extended global programmes are being developed to improve prediction and monitoring of climatic changes and their effects. Recognizing the lack of a comprehensive programme for monitoring of climate-related changes relevant to the marine and coastal environment, UNEP, jointly with IOC and WMO, undertook the development of a programme for a long-term global monitoring system for coastal and near-shore zone observations, including physical and biological parameters. The programme will provide data on global changes with special reference to those associated with or attributable to the impacts of expected climate changes, such as sea-level rise. It is expected to draw on the existing and planned observation networks in the framework of programmes such as Earthwatch, the Global Environmental Monitoring System (GEMS), the World Weather Watch (WWW), the Global Investigation of Pollution in the Marine Environment (GIPME), the Integrated Global Ocean Services System (IGOSS),the Global Sea Level Observing System (GLOSS), the Tropical Ocean and Global Atmosphere Programme (TOGA), the World Ocean Circulation Experiment (WOCE), the Joint Global Ocean Flux Study (JGOFS), the International Geosphere-Biosphere Programmes (IGBP), Man and the Biosphere, and others. It will collect information on sea-level changes and coastal flooding based on the IOC's GLOSS, which, when integrated with other data, will give global estimates of the actual rate of sea-level rise to allow confirmation or modification of present predictions. It will also provide information on the responses of natural systems to rising sea levels. There are plans for direct involvement of developing countries in data collection, management and use. A pilot phase of the programme is expected to begin shortly.

23. UNEP, as the organization catalysing and coordinating the efforts of the United Nations system in environmental matters, started to consider the problem of sea-level rise several years ago. It has stimulated the improvement of knowledge about the causes and the expected course of climatic changes and their consequences for sea-level rise through encouragement and support for scientific programmes, such as the World Climate Research Programme (WCRP) and IGBP. It has concentrated its own efforts on analyses of the potential impact of expected climatic changes and sea-level rise on ecosystems and on social and economic structures and activities. These are expected to assist Governments in the development of policy options and management measures that may avoid or mitigate the negative consequences of expected sea-level rise and other climate-induced changes.

24. The Oceans and Coastal Areas Programme Activity Centre of UNEP, in cooperation with IOC and several other intergovernmental and non-governmental organizations, launched, coordinated and financially supported regional task teams on the implications of climatic changes. Six were established in 1987 for regions covered by the UNEP Regional Seas Programme (Mediterranean, wider Caribbean, South Pacific, East Asian seas, South Asian seas and South-East Pacific regions) with the initial objective of preparing regional overviews and case-studies on the possible impact of expected climate changes and sea-level rise on the coastal and marine ecological systems, as well as on the social and economic structures and activities of their respective regions. Agricultural, social and economic features of the countries were evaluated by

individual or small groups of specialists and combined with the results of oceanographic, coastal geomorphological and hydrological assessments. Additional task teams were established in 1989 for the west and central African region and for the eastern African region and in 1990 for the Kuwait Action Plan region. The establishment of task teams for the Black Sea and for the Red Sea is under consideration. These task teams cover 109 countries and have included approximately 200 specialists from a wide range of disciplines. The results of their analysis are being brought to the attention of policy makers, managers and administrators to assist them in formulation of suitable policy options and in implementation of mitigating measures. For example, an intergovernmental meeting on the results of the South Pacific task team was held at Majuro, Marshall Islands, in July 1989. A programme of further studies and assistance to the Pacific island States and territories to enhance their response capabilities to the expected impact of climatic changes and sea-level rise is under way. In the Mediterranean, six site-specific case-studies are being launched: three in island areas (Rhodes, Malta and the northern Adriatic islands) and three in coastal zones (Ismir Bay, Kastela Bay, Syrian coast). Case-studies in other regions are in preparation.

25. UNEP has also collaborated with the International Union for the Conservation of Native and Natural Resources (IUCN) in the development of a database on the islands of the world, which will allow the classification of islands by geographic, biological and socio-economic criteria that will help to identify those islands particularly at risk from sea-level rise and to determine the scale of the necessary response.

V. CONCLUSIONS

26. Sea-level rise is clearly a problem that will preoccupy the international community for a long time to come. On the basis of the information available at present, it is possible to draw the following conclusions:

(a) The expected impact of sea-level rise on islands and low-lying coastal areas may become a decisive factor in the future social and economic development of these areas. The stress on coastal human activities and infrastructures (such as coastal settlements), as well as on marine and low-lying coastal ecosystems (coral reefs, mangroves, agriculture) and on freshwater resources may result in irreversible changes leading to considerable loss of territory and decreased carrying capacity of many areas.

(b) Coastal settlements and structures (such as harbours and airports) are likely to be specifically vulnerable to sea-level rise. Engineering solutions to problems caused by sea-level rise will not be applicable as realistic long-term solutions on a large scale; their application will be limited to specific sites only. Social adaptations and changes in land-use practices seem the most appropriate response.

(c) More attention needs to be given to conservation of soil, groundwater, mangroves and coral reefs because they contribute to the

resilience of the coastal environment, which is expected to be subject to the impact of rising sea levels.

(d) The direct impact of the expected rise in sea level and temperature will be highly site-specific and will be exacerbated by socio-economic factors, such as population increases and present development plans, as well as by tectonic movements exceeding the magnitude and rate of expected sea-level rise. Therefore, in searching for suitable policy options and management measures all these factors have to be kept in mind.

27. In view of the highly specific nature and complexity of policy options and management measures that may be applicable to individual sites, or to whole islands, in-depth assessment of the potential impact of sea-level rise and expected climate changes and the formulation of long-term development plans for individual island States and coastal areas is suggested as the most promising follow-up. Such assessments and plans, aiming at sustainable and environmentally sound development, should be based on the geographic and ecological characteristics of the States, on the States' present social and economic development, as well as on the goal of future sustainable development as perceived by the peoples of these States.

28. In order to determine priority areas for action, work is needed to develop methods of comparative vulnerability assessment for sea-level rise. Such methods might be based on integrated geographic databanks covering the physical, biological, social and economic factors. The approaches should permit modelling and comparative assessments for countries and areas having quite different characteristics. They should allow clear definitions of the objectives for action in assessing relative vulnerability.

29. The immediate coastline subject to sea-level rise is a neglected area, avoided in the past by both land surveyors and hydrographic survey vessels, on which little precise information is available. New efforts are needed to collect the data necessary to determine the effects of gradual sea-level rise on particular coastlines. Following initial identification of the geological, geomorphological and physical ocean characteristics and processes of importance in coastal zones, models need to be constructed to provide a measure of physical vulnerability. The models should incorporate data relating to tectonic land movements, tidal range, wave climate, sediment composition and flux, slope of the coastal plain, beach plan form and seasonal characteristics in climatic variables.

VI. PROPOSED ACTION BY THE GENERAL ASSEMBLY

30. The General Assembly is invited to note the critical problems that will be created for many islands and low-lying coastal areas by sea-level rise resulting from climate change. It may wish to urge the international community to develop special programmes of assistance to islands in the integrated planning of their development and environmental management to reduce their vulnerability to sea-level rise. It may further wish to urge the

international community to support improved data collection on and monitoring of coastal areas and sea level as part assessments of vulnerability to sea-level rise and of long-term monitoring of parameters related to or affected by expected climatic changes. Such monitoring should be integrated into systems designed to give the earliest possible warning that sea levels are in fact rising as predicted.

31. The islands and low-lying coastal areas will suffer, through sea-level rise, some of the most extreme effects of expected climatic changes. Yet most of these areas, at least in the developing countries, have contributed little if anything to the origins of the problem. International solidarity will be necessary to assist the people of such areas to cope with the situation and specific mechanisms for this should be included in the proposed framework convention on climate change and in the decisions of the United Nations Conference on Environment and Development.